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13. ABSTRACT (Maximum 200 words) The objective of this workshop was to bring together researchers, manufacturers and potential users of MEMS and experts in tribology (including mechanics, mechanical properties and surface modification) so that the MEMS community could better understand the tribology expertise and the tribology community could better understand the major problems on hand and identify critical research issues facing MEMS industry. There were three specific objectives of the workshop. The first was to provide tutorial on MEMS technology and state-of-the-art of tribology for education of tribology and MEMS community, respectively. The second objective was to share whatever tribological understanding of MEMS devices exists. The third objective was to identify tribology research issues and opportunities and general directions for tribology in MEMS research which were accomplished via breakout sessions and a panel discussion. Since the objective of the first part of the workshop was to provide tutorials, we had a large number of lectures of short durations followed by lectures on tribology of MEMS, mechanical property measurements, modification and characterization of surfaces, and breakout sessions and a panel discussion. A side benefit of this workshop was to bring macro- and microtribologists together.					
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Final Report on Tribology Issues and Opportunities in MEMS Workshop

PREFACE

Micro Electro Mechanical Systems (MEMS) is already about a billion dollars a year industry and is growing rapidly. So far major emphasis has been placed on the fabrication processes for various devices. There are serious issues related to tribology, mechanics, surface chemistry and materials science in the operation and manufacturing of many MEMS devices and these issues are preventing an even faster commercialization. Very little is understood about tribology and mechanical properties on micro- to nanoscales of the materials used in the construction of MEMS devices. The MEMS community needs to be exposed to the state-of-the-art of tribology and vice versa.

Fundamental understanding of friction/stiction, wear and the role of surface contamination and environmental debris in micro devices is required. There are significant adhesion, friction and wear issues in manufacturing and actual use, facing the MEMS industry. Very little is understood about the tribology of bulk silicon and polysilicon films used in the construction of these microdevices. These issues are based on surface phenomena and cannot be scaled down linearly and these become increasingly important with the small size of the devices. Continuum theory breaks down in the analyses, e.g. in fluid flow of micro-scale devices. Mechanical properties of polysilicon and other films are not well characterized. Roughness optimization can help in tribological improvements. Monolayers of lubricants and other materials need to be developed for ultra-low friction and near zero wear. Hard coatings and ion implantation techniques hold promise.

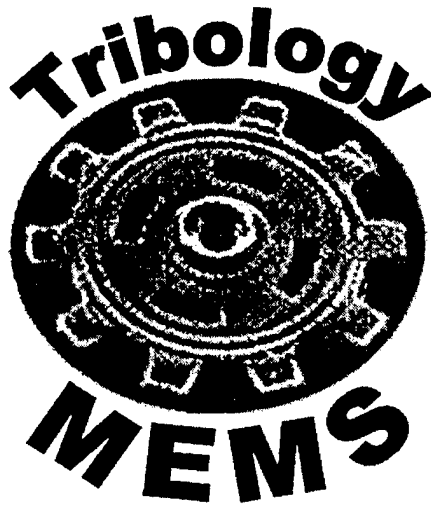
Better tribological understanding of MEMS will advance the state-of-the-art in micromachining and the IC industry, in general. For example, better understanding will contribute to better performance prediction for micromachined pressure sensors, accelerometers and gyro's as well as a better understanding of stiction behavior of micro-mirrors and micromotors and of the influence of roughness on micro-fluids.

The objective of this workshop was to bring together researchers, manufacturers and potential users of MEMS and experts in tribology (including mechanics, mechanical properties and surface modification) so that the MEMS community could better understand the tribology expertise and the tribology community could better understand the major problems on hand and identify critical research issues facing MEMS industry. There were three specific objectives of the workshop. The first was to provide tutorials on MEMS technology and state-of-the-art of tribology for education of tribology and MEMS community, respectively. The second objective was to share whatever tribological understanding of MEMS devices exists. The third objective was to identify tribology research issues and opportunities and general directions for tribology in MEMS research, which were accomplished via breakout sessions and a panel discussion. Since the objective of the first part of the workshop was to provide tutorials, we had a large number of lectures of short durations followed by lectures on tribology of MEMS, mechanical property measurements, modification and characterization of surfaces, and breakout sessions and a panel discussion. A side benefit of this workshop was to bring macro- and microtribologists together.

We assembled individuals who are active in research and manufacturing of MEMS devices or are potential users of this technology. We also invited experts in macro- and microtribology, surface modification and mechanical property measurement arenas from industry, government and academia. The micro/nanotribology community can play a pivotal role. Tribological issues in MEMS are closely related to those faced today by magnetic storage devices community, which were also invited to attend. Furthermore, a special effort was made to attract students and younger researchers from the U.S. and overseas. The response to the course workshop was overwhelming. We had 122 participants from eleven countries including Belarus, Belgium, Germany, India, Japan, Netherlands, Norway, Poland, Switzerland, U.K. and U.S.A. Participants ranged from undergraduate students in engineering to very senior researchers. A total of 46 oral and 27 poster presentations were made at this workshop in addition to four breakout sessions and a panel discussion.

Invited lectures and selected contributed articles have been published in a hard volume by Kluwer Academic Publishers B.V. The workshop proceeding contains 46 articles, 4 breakout session reports, and a panel discussion report.

Professor Bharat Bhushan
Workshop Director
Columbus, Ohio, U.S.A.
June 1998



Tribology Issues and Opportunities in MEMS

Edited by

Bharat Bhushan

CONTENTS

Preface	
1. MEMS Fabrication Techniques	
MEMS R&D in Europe	
L. Hermans	
Integrated MEMS in Conventional CMOS	
G. K. Fedder	
Facilitating Choices of Machining Tools and Materials for 'Miniaturization Science': A Review	
M. Madou	
Microfabrication Technologies for High Performance Microactuators	
F. Michel and W. Ehrfeld	
Surface Characterization of Non-Lithographic Micromachining	
C.R. Friedrich and R.O. Warrington	
2. MEMS Applications and Tribology Issues	
Biosensors and Microfluidic Systems	
P.J. Hesketh, S. Zivanovic, S. Pak, B. Ilic, L. St.Clair, B. Shih, K.Y. Chung, J.C. Cunneen, S. Cariffini, J.G. Boyd, J.R. Stetter, S.M. Lunte, and G.S. Wilson	
Power MEMS Materials and Structures	
S.M. Spearing and K.S. Chen	
MEMS Opportunities in Accelerometers and Gyros and the Microtribology Problems Limiting Commercialization	
R.E. Sulouff	
New Technology and Applications at Lucas NovaSensor	
K.R. Williams	
3. State-of-the-Art of Tribology: Macroscale Processes	
Rough Surface Characterization	
J.H. Tripp	
Frictional Instabilities	
N.S. Eiss	
Wear of Ceramics and Metals	
T.E. Fischer	
Mechanics of Wear: From Conventional Components to MEMS	

F.J. Franklin and A. Kapoor

Rheological Modeling of Thin Film Lubrication

J.A. Tichy

Surface Roughness Induced Effects in Hydrodynamic Lubrication

Kristian Tonder

Transition From Elastohydrodynamic to Partial Lubrication

H.S. Hsiao, B.J. Hamrock, S.K. Sharma, and J.H. Tripp

4. State-of-the-Art of Tribology: Micro- to Nanoscale Processes

Micro/Nanotribology: State of the Art and Its Applications

B. Bhushan

Pulsed Force Mode: A New Method for Characterizing Thin Silane Films by Adhesive Force Measurements

S. Hild, U. Krottil, and O. Marti

Formation of Nanometer-Scale Contacts to Viscoelastic Materials

K.J. Wahl and W.N. Unertl

Nanotribology of Vapor-Phase Lubricants

J. Krim and M. Abdelmaksoud

The Tribology of Hydrocarbon Surfaces Investigated Using Molecular Dynamics

J.A. Harrison, S.J. Stuart, and M.D. Perry

Dual-Axis Piezoresistive AFM Cantilever For Independent Detection of Vertical and Lateral Forces

B.W. Chui, T.W. Kenny, H.J. Mamin, B.D. Terris, and D. Rugar

Statistical Thermodynamic Treatment of the AFM Tip in Liquid

K.Koga, X.C. Zeng, and D.J. Diestler

5. Tribology of MEMS Components and Materials

Tribological Issues of Polysilicon Surface-Micromachining

J.J. Sniegowski

Advantages and Limitations of Silicon as a Bearing Material for MEMS Applications

M.N. Gardos

Surface Force Induced Failures in Microelectromechanical Systems

C.H. Mastrangelo

Development, Fabrication and Testing of a Multi-Stage Micro Gear System

C. Thürigen, W. Ehrfeld, B. Hagemann, H. Lehr, and F. Michel

Analysis of Gear Tooth Performance of Mechanically-Coupled, Outer-Rotor Polysilicon
Micromotors
K.C. Stark, M. Mehregany, and S.M. Phillips

Micro/Nanotribological Studies of Single-Crystal Silicon and Polysilicon
and SiC Films for Use in MEMS Devices
B. Bhushan, S. Sundararajan, X. Li, C.A. Zorman, and M. Mehregany

Phase Transformations in Semiconductors Under Contact Loading
Y.Gogotsi, M.S. Rosenberg, A. Kailer, K.G. Nickel

Influence of Water Adsorption on Microtribology of Micromachines
N. Ohmae

Tribological Effects of Surface Roughness in MEMS Devices
L. Lin

Active Friction Control Using Ultrasonic Vibration
V. Scherer, W. Arnold, and B. Bhushan

Contact Resistance Measurements and Modeling of An Electrostatically Actuated
Microswitch
S. Majumder, N.E. McGruer, P.N. Zavracky, G.G. Adams, R.H. Morrison, and J. Krim ..

Metrology For MEMS Tribology
N.V. Gitis

6. Mechanical Property Measurements

Mechanical Property Determination Using Nanoindentation Techniques
C.J. McHargue

Stress in Thin Films for MEMS Actuators
P.H. Holloway, J.Gorrell, and K. Shannon, III

Reliability and Fatigue Testing of MEMS
C. Muhlstein and S. Brown

7. Modification and Characterization of Surfaces

Surface Modification and Mechanical Properties of Bulk Silicon
M. Scherge and J.A. Schaefer

Microfriction and Microwear Experiments on Metal Containing Amorphous Hydrocarbon
Hard Coatings Using an Atomic Force Microscope
K.I. Schiffmann

Formation of Carbon Films on Ceramic Carbides by High Temperature Chlorination
M. McNallan, Y. Gogotsi, and I. Jeon

Deposition and Characterization of Diamond-Like Materials
T.C. Ovaert, R. Messier, L.J. Pilione, R. Collins, J. Lee, W. Otano-Rivera,
and J.A. Zapien

Wear and Nanomechanical Studies of Silicon Oxide and Silicon Nitride Thin Films for
MEMS Applications
Z. Rymuza, Z. Kusznierevich, M. Misiak, K. Schmidt-Szalowski, Z. Rzanek-Boroch,
and J. Sentek

a-SiC Thin Films Deposited Using Pulsed Laser Ablation of Graphite and Magnetron
Sputtering of Silicon onto Steel Substrates at Room Temperature
J.J. Nainaparampil

Lubrication of Polysilicon Micromechanisms with Alkylsiloxane Self-Assembled
Monolayers: Coefficient of Static Friction Measurements
U. Srinivasan, R.T. Howe, and R. Maboudian

Tribological Properties of Modified MEMS Surfaces
V.V. Tsukruk, T. Nguyen, M. Lemieux, J. Hazel, W.H. Weber, V.V. Shevchenko, N.
Klimenko, and E. Sheludko

8. Breakout Sessions Report

Tribology Research in MEMS
M. Madou

Mechanisms of Nano-Scale Tribology and Instrumentation for MEMS Devices
K. Komvopoulos

Breakout Session Report: Lubricants, Overcoats and Surface Modification Techniques
D.A. Rigney

Breakout Session: Group 4. Mechanical Property Measurements
C.J. McHargue

9. Panel Discussion Report

Tribology Issues and Opportunities in MEMS
C.R. Friedrich

List of Participants

Subject Index

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